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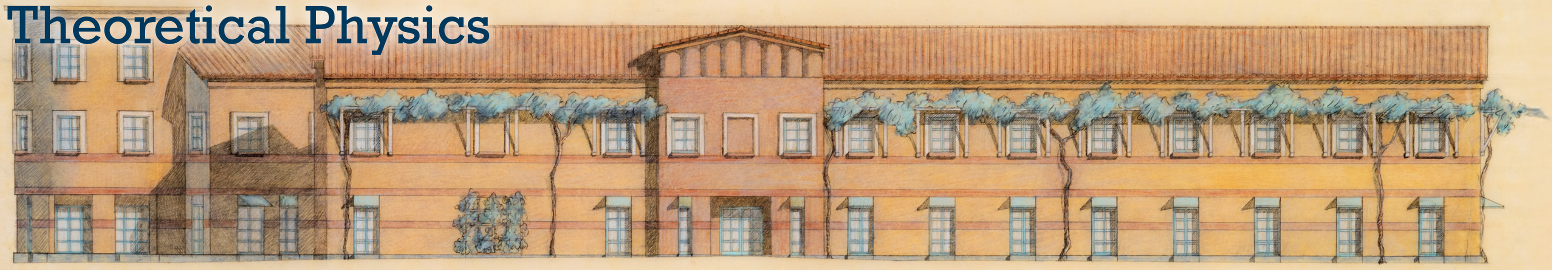

NORTH ELEVATION
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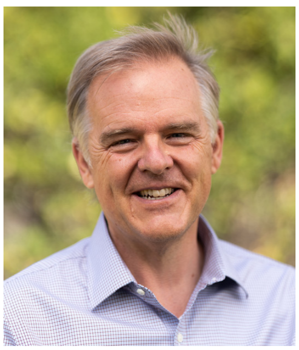
MICHAEL GRAVES, ARCHITECT

# Newsletter

www.kitp.ucsb.edu | Fall 2024



*Lars Bildsten*

We celebrated 30 years in Kohn Hall this summer. Prolonged leadership created this unique infrastructure that enables the hallmark of our mission: forming collaborations! Initiated and achieved by then Director Jim Langer, this architectural gem of the UC Santa Barbara campus was designed by Michael Graves. The banner image is a rendering from the original design, which Graves also continued when we expanded the building 20 years ago under the direction of then Director David Gross. Our celebration brought together campus leadership, members of UCSB's physics department and the remaining KITP Founders to reminisce about what's been achieved!

This year, six KITP Postdocs advanced to new positions in industry and academia. Evan Anders is a member of the technical staff at Anthropic. Wenping Cui is a Postdoctoral Research Associate at Princeton, Ying Zhao is a postdoctoral researcher at MIT, and Shang Liu is a Postdoctoral Scholar Research Associate at Caltech and will then join the faculty at the Chinese Academy of Sciences in Beijing. Urban Seifert is a Research Group Leader at the University of Cologne in Germany, and Izabella Lovas will be an Advanced Fellow at ETH Zurich in Switzerland.

The newly arrived postdocs span most of physics. Fatih Dinç is coming from Stanford to work in biophysics. In High Energy Physics, Alexandre Homrich and Amalia Madden come from Perimeter Institute, while Bruno Scheihing comes from MIT. In condensed matter physics, the new arrivals are Thomas Kiely from Cornell and Wen Wang from Stanford. Chris Ni comes from U. Toronto to pursue astrophysics. All are already actively engaging in KITP's intellectual life.

Ever since I started to spend time at the site of the Munger Physics Residence, I had an appreciation for its natural beauty. Indeed, on first visits there to monitor the "noise", the loudest ones came from the birds in the wetland. Pages 2 and 3 are an excellent summary written by Demi Cain (KITP's Development Coordinator) of why this site is so unique: its adjacency to well-curated wetlands. We did all we could in our design to ensure that our visitors would appreciate this location.

KITP visitors at all career-stages benefit from their time with us, and it's even better when we can tell their stories. Page 4 is the story of Mukund Thattai, an early graduate fellow in 2003 and program coordinator in 2010. This story tells his scientific trajectory in biology and physics that led to his award of the 2023 Infosys Prize. Following on page 5 is the scientific story of a breakthrough in planet formation theory that occurred here in 2004 for KITP visitor Andrew Youdin. Yes, these stories appear "old," but in reality, basic scientific research takes time to yield and have impact. Thankfully KITP is a lasting institution that can create these collaborations, nurture them and witness their later appreciation by the scientific community.

A few years ago, we established the KITP Fellows program (supported by the Heising-Simons Foundation) aimed at supporting the science and mentoring of faculty at teaching intensive minority-serving institutions. KITP Fellow Kausik Das has continued his engagement with KITP, returning to participate in our Teachers' Conference earlier this year. The article on page 6 describes the scientific connections he made while here and the lasting value they are providing to his undergraduate mentoring.

The final article is about the science achieved by KITP Postdoc Fridtjof Brauns in collaboration with Professor Cristina Marchetti of UCSB's physics department. We encourage our postdocs to explore new arenas of research and this scientific exploration sheds light on how patterns form in materials, as well as nature. I was happy to include some photos of murmurations (a naturally occurring phenomena they discussed) during a visit to UCSB's Sedgwick Reserve.

I close with a note of sadness. In early September, we learned that Professor Doug Eardley had passed. Doug was an early KITP Permanent Member with a specialty in general relativity and its astrophysical applications. In addition to his many pieces of high-impact science, Doug also innovated at the institute with the envisioning, creation and operation of what became KITP Online. Started in 1997, this is the video archive of all talks at KITP--an international resource of over 23,000 talks that are watched every day for over 500 hours. Over the last few years, the curation of this effort transitioned to KITP staff member Alina Gutierrez, but Doug remained engaged and available for technical input on all things IT.

Thanks to all of you for your support and engagement here at KITP!

*- Lars Bildsten, KITP Director*

# Nature at the Munger Physics Residence

MAKSYM SERBYN

*Red-shouldered hawk perched on the Residence rooftop*

Over the last seven years that the Charles T. Munger Physics Residence has been housing KITP's visiting researchers, an unexpected member of the community has become a local celebrity among the building's staff and guests. With deep brown eyes and a blanket of feathers that glow a rusty-red color in the sunlight, the beloved red-shouldered hawk is a bird found commonly in the area. While they typically nest in oak, pine and eucalyptus trees, these hawks have made quite the impression by making regular appearances on the balconies and rooftops of the Residence. They seem to show little concern about attracting attention, sometimes even putting on a show for lucky passersby. One quiet afternoon, for instance, staff were walking along the patio when a flapping noise caught their attention. Within seconds, one of the resident hawks quickly swooped down only a few yards in front of them, then took off with a thin, black snake wriggling and writhing between its sharp beak. Serendipitous encounters like these have turned the red-shouldered hawk into one symbol of the natural beauty visitors can find just steps away from their rooms.

When guests look north towards the Santa Ynez Mountains, they have a picturesque view of protected wetlands, chaparral, and grasslands situated between UCSB's Storke Field and Los Carneros Road. This region is a small portion of coastal land that was historically inhabited by the Chumash Indigenous Peoples for thousands of years.

Today, the approximately six-acre stretch of land constitutes the San Clemente Habitat Restoration Site, which is one of several projects undertaken by UCSB's Cheadle Center for Biodiversity and Ecological Restoration. The Cheadle Center manages over 340 acres of open spaces surrounding UCSB, leads restoration and conversation projects, and maintains collections of local plant and animal species used for biodiversity research. The San Clemente site was established in 2005 to mitigate the impacts of the adjacent San Clemente Villages housing development for UCSB graduate students. This site is one of several restoration efforts associated with campus housing including Manzanita Villages, Sierra Madre, San Joaquin and Ocean Walk.

DEMI CAIN

*Northern view from the Residence*

CALFLORA.ORG / ERIC KOBERLE

*Southern tarplant*

THE CHEADLE CENTER

*Before and after images of the San Clemente Restoration site*

Prior to 2005, the San Clemente site consisted of existing wetlands and was dominated by non-native grasses and some native plant species. The most notable native plant whose protection was an important factor in establishing the project is the Southern tarplant. Though the species doesn't have state or federal protection status, the California Native Plant Society (CNPS) classifies it as a plant considered rare, threatened, or endangered in California and elsewhere.

Another hallmark of the San Clemente site is its stormwater management system, which captures and filters 100% of the stormwater runoff from the San Clemente housing complex. The system is made up of multiple bioswales and a one-acre vernal marsh dedicated to collecting stormwater and is full of native sedges, rushes, and other wetland species. The water is filtered through plants and soils that remove pollutants—a process called biofiltration—and then it hydrates the surrounding landscape.

The restoration of San Clemente was an extensive project that took five years to construct. The land was first carefully graded to support the flow pattern of stormwater as it moves throughout the wetlands, and to support adequate basins to hold the water for biofiltration. This resulted in a rolling landscape similar to the natural conditions found in an undisturbed wetland. After grading was completed in 2006, various erosion control tools like netting, dams, and other materials were installed to prevent sedimentation of the site's hydrological features and the nearby Storke Wetland and Goleta Slough.

The next step in restoration was large-scale weeding to reduce the abundance of non-native plants and create better conditions for native species to thrive. By focusing on the removal of non-natives that compete with native species, less revegetation was needed. Now, more than 100 native plant species thrive in the San Clemente site alone. Trees like coast live oak, Western sycamore, and black cottonwood were some of the project's first plantings because they take the longest to mature, and are now part of the visual landscape our visitors enjoy. Flowering plants also visible are the California poppy, blue eyed grass, red maids, California fuchsia, owl's clover, sacred datura, bush sunflower, and many other species that produce beautiful blooms.

THE CHEADLE CENTER

*Blue eyed grass (left) and owl's clover (right)*

Visitors may also be fortunate enough to see the variety of animal species that frequent the site. In addition to the red-shouldered hawks, there are birds like California scrub jays, Western bluebirds, great blue herons, Anna's hummingbirds, red-winged blackbirds, killdeer and lesser goldfinches, among a multitude of others. In fact, illustrations of a number of these birds by John James Audubon adorn the walls of the Residence's Kaplan Dining Room. Other wildlife belonging to the area are Pacific chorus frogs, monarch butterflies, common buckeyes, alligator lizards, western skinks, and brush rabbits, to name a few.

NATIONAL AUDUBON SOCIETY

Lisa Stratton, the Cheadle Center's Director of Ecosystem Management, leads the team that maintains the site on a regular basis through hand weeding and removing larger shrubs to keep open habitats and reduce the risk of fires. Much of the bulrush that takes over the wetlands is mowed down every other year to allow for more water and new plant growth—which is "a big operation," according to Stratton.

Restoration sites like San Clemente help the Cheadle Center carry out an important part of its mission, which is offering classes and internships to train UCSB students in ecological restoration and gain experience in field research. At the Munger Residence, scientists and their families are encouraged to read the recently installed signage looking out onto the patio or watch for friendly hawks and other animals while on the outdoor playground. It is a special opportunity for residents and guests in the San Clemente Villages and Munger Physics Residence to stay so close to this compact hub that provides habitat to wildlife, protects native plant populations, and showcases some of this region's abundant biodiversity.

*by Demi Cain*
*KITP Development Coordinator*

# Free to Speculate

INFOSYS SCIENCE FOUNDATION

*Mukund Thattai presenting at the Infosys Prize Ceremony, January 2024*

The convergence of physics and biology has enriched contemporary science research, even leading to new fields like evolutionary cell biology, which Professor Mukund Thattai (National Center for Biological Sciences/NCBS, India) has seen develop from its early stages. The "accidental biologist" has been one of the key contributors to this growing field over the last two decades, and his interdisciplinary work earned him the 2023 Infosys Prize.

Thattai studies how the eukaryotic cell developed its network of endomembrane organelles with many complex functions, such as transporting cargo within and out of the cell. Vesicles move molecules like proteins that are too large to pass through the cell membrane on their own. He explains that unlike the way cargo trucks are assigned routes ahead of time, within the cell, the cargo tells vesicles where to go. He found that "it's the behavior of the proteins that ultimately define which organelles will persist and how they connect to each other." Scientists can examine the proteins found in eukaryotes up to 1.5 billion years ago to provide insight into organelle evolution.

Like the organelles he studies, the questions that Thattai ponders today took time to evolve. During a visit home to India in his first year of grad school at MIT, Thattai went to a biology lecture, coincidentally, at NCBS. The lecture introduced him to biology in a way that fascinated him. Once he returned to MIT, he sought out courses and labs that were using the mathematical models he was familiar with to describe and accurately predict biological phenomena. Later, when he came to KITP as a Graduate Fellow in 2003 and attended the program *Biomolecular Networks,* he worked with KITP Permanent Member Boris Shraiman. That's when Thattai says he "figured out the kinds of questions to start asking."

Thattai was accepted into a new NCBS program after completing his Ph.D. He set up a lab to build genetic networks with quantitative methods, but he soon realized that he didn't understand biology at all. With encouragement from Shraiman and his NCBS colleagues, Thattai came back to KITP in 2010 to coordinate the program *Evolutionary Perspectives on Mechanisms of Cellular Organization.* The coordinators wanted a crash course on cell biology, so they invited scientists working on every system within the cell they could identify. They also requested that speakers prepare to discuss evolution even if it wasn't part of their work. "The fact that you could look at cells and ask evolutionary questions and physics questions combined—very few people were doing this." According to Thattai, cell biologist Mark Field was the only person to give a talk on the program's topic because it was such a novel area of interest. "Everybody came wearing a different hat because they felt free to speculate in this special place. The ability to step back from your research and have the space to talk and think in a sustained way, without any pressure to do anything else, that's what KITP is all about."


MUKUND THATTAI

*Thattai's notebook from the 2010 KITP program*

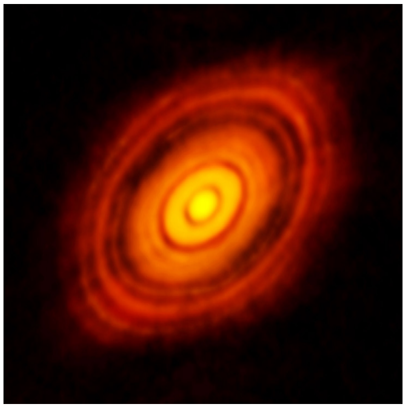
KITP remains a special place to Thattai. "Everything I'm working on up to today was, almost literally, from questions that emerged during that program in 2010." He even kept his notebook from the program. It is full of questions that he understands better now, and many he is still working through. His greatest aspiration is to bring an evolutionary framework to the forefront of biological questions. Advancements in genome sequencing have revealed many new organisms to study, and he is excited about the progress being made on creating artificial cells in the lab.

Thattai feels hopeful about the future of his field and biophysics more broadly. After all, he is a physicist at a biological research institution who won the Infosys Prize in the Physical Sciences category for his work in evolutionary cell biology. He believes this accomplishment sends a positive message to future generations that scientific study is not so rigid. This has been reinforced by influential publications like the National Academy of Science's 2022 "Physics of Life," which was the first of its kind to acknowledge this branch of physics. At NCBS, he helped establish the Simons Centre for the Study of Living Machines, as well as two biophysics courses for graduate students and postdocs. It is encouraging that this interdisciplinary approach has gained support from the scientific community through efforts like Thattai's and his colleagues like Shraiman, who initiated and leads the Santa Barbara Advanced School of Quantitative Biology (QBio) at KITP.

Thattai feels fortunate to have experienced the strong institutional backing he found at his own NCBS, and through his time at KITP. At the core of these organizations, however, are people like Thattai whose passion and dedication move science forward.

*by Demi Cain*
*KITP Development Coordinator*

# Streaming Instability: Bringing Dust Particles and Scientists Together



ALMA (NRAO/ESO/NAOJ); C. BROGAN, B. SAXTON (NRAO/AUI/NSF)

*ALMA image of the young star HL Tau and its protoplanetary disk*

The Earth and other planets started out as particles of dust in the disk of a young star. Those particles found each other and started to clump, bound together by electrostatic forces similar to the irritating ones that make plastic film wrappers stick to your hands. The clumps grew into larger, bumpy, comet-like bodies called planetesimals, and eventually became large enough to become true planets, which are spheres held together by their own gravitational fields. To do so, they had to pass through a mysterious transition where they were too small for gravitation to hold them together but too big for sticking forces alone to do the job. How did they make it through?

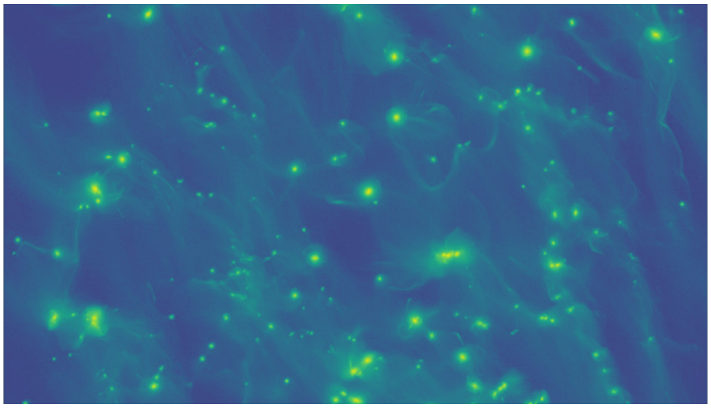
The sticking forces holding a planetesimal together are surface forces. As the body grows, its surface gets smaller and smaller relative to its mass and it becomes less and less sticky. Eventually it reaches a point where stickiness alone shouldn't be sufficient for it to grow, but it isn't yet large enough for gravity to take over. That awkward "point" is called the meter size barrier, but it is actually a gulf spanning several orders of magnitude—in some stickiness vs. gravity models of early planet formation, clumps as small as a centimeter in diameter and as large as several kilometers shouldn't exist.

UNIVERSITY OF ARIZONA

*Andrew Youdin*

In 2004, scientists gathered at KITP for the program *Planet Formation: Terrestrial and Extra Solar* to rethink that and other questions about planetary formation and evolution. One of them was Andrew Youdin (Steward Observatory, Univ. of Arizona). Youdin was just beginning his first postdoc at Princeton. He planned to investigate the meter size barrier in his postdoctoral work and was searching for the right angle on the problem. That angle began taking shape during a conversation with another program participant, Gordon Ogilvie (Univ. of Cambridge). Protoplanetary disks are about 99% gas and only 1% dust; at the time, most mathematical models of the gas's behavior considered only the gaseous component's modes, the oscillations in its behavior that occur when it is disturbed by various forces. Ogilvie suggested looking at what happens to the gas's oscillations when its interactions with dust were included in the model.

Youdin started building the model and made rapid progress. He explains: "I found that the well-known equilibrium state of



RIXIN LI (CORNELL) AND ANDREW YOUDIN (U. OF ARIZONA)

*Dense pebble clumps formed by the streaming instability after they have started to collapse into 10-100km planetesimals*

dust radially drifting through gas (due to large scale pressure gradients) is unstable to what we called the 'streaming instability,' [a fluid-mechanical phenomenon involved in other astrophysical processes] which produces particle clumping to aid planet formation." Essentially, the dust particles in a protoplanetary disk rotate slightly faster than the gas, which in turn causes a drag force on the dust. When the dust particles slow down, they begin to accelerate toward the planet. "It turns out," Youdin continues, "that this falling-in happens fastest for things that are around a meter in size, so this meter size barrier for things sticking is also a meteor size barrier for falling into the star."

This would seem to add to our difficulties, but the streaming instability model also includes the gas's oscillations. The gas pushes back on the dust particles, and the new model showed that considering the back-reaction yields a positive feedback of sorts. "The effect of particles starting to clump together is to create a reaction in the gas that causes more particles to come together."

The streaming instability model demonstrated that dynamical effects play a large role at the early stages of planetesimal formation, upending previous views that particle sticking was the only important mechanism. It grew into one of the 21st century's leading ideas on planet formation and has spawned a sub-field of its own. "Numerical simulations of the streaming instability (now with much more physics included than the original analysis) are now a sub-field of their own, with a code comparison project currently in the works!"

Grateful for his seminal advice, Youdin had asked Ogilvie if he wanted to join that original paper, which has now been cited nearly 800 times. "Claiming that he had only given me obvious (to him!) advice, he declined." Ogilvie's choice could be called humble, even generous. He was a relatively senior and well-recognized scientist and Youdin was just getting started. "It's very much in the spirit of what KITP is," Youdin says. " You don't come trying to keep secrets; it's a place people come to share ideas."

*by Maggie Sherriffs*
*KITP Special Programs & Evaluation Manager*

# Building Systems of Support

*Kausik Das*

Scientific excellence drives all of KITP's endeavors, and it is achieved through unfettered intellectual exchanges between each scientist who visits. Extended interaction times and physical spaces for gathering are provided, and efforts are made to create an environment that is truly welcoming of the diversity of ideas and people within the scientific community. In 2022, KITP launched a new initiative funded by the Heising-Simons Foundation, the KITP Fellows program, that takes this one step further by more intently engaging faculty from non-R1 institutions (typically with higher teaching loads) that are also minority-serving institutions (MSI). The MSIs requirement is to acknowledge and ultimately address the underrepresentation of minority populations in physics research and academia. By providing faculty at these institutions with time to engage in research and expand their networks at KITP, what they gain from their fellowship is brought back to their classrooms to directly benefit their students.

The far-reaching impact of the KITP Fellows program was recently demonstrated through the experience of KITP Fellow Kausiksankar Das of University of Maryland Eastern Shore (UMES). Das visited in 2023 and was eager for the intellectual engagement with what he characterizes as "frontline researchers" at the institute.

During one of KITP's daily cookie and coffee breaks, he met Harvard professor Cassandra Extavour and a postdoctoral researcher working in her lab, Suhrid Ghosh. The group "discussed ways to integrate HBCU students into cutting-edge research," says Das, which was his priority during the fellowship. HBCUs, like UMES, are historically Black colleges and universities that were established to educate Black Americans during the era of racial segregation. HBCUs welcome students from all backgrounds, but their mission is to promote access to higher education within the Black community.

Das and Extavour kept in touch after his visit, and the connection led to exciting collaborations, like Extavour speaking at a UMES seminar in 2025. Without KITP, Das explains, he likely would not have met the Harvard researchers with whom he has built a fruitful relationship that is already making an impact at his university.

As a scientist and an educator, Das holds a holistic view on how to support students whose identities and backgrounds are intertwined with "historical baggage" that can put them at a disadvantage. In his experience, it is not sufficient to simply fund and establish a new program, "it's the care and the support system that you need" to make a difference for students. It is up to those with influence, such as faculty, administrators, policymakers, and entire agencies or institutions to promote ideals and create opportunities that "build self-efficacy…we need to bring it out." He maintains that when students feel like others believe in their abilities and are given a place to belong, it makes them want to apply themselves to their fullest potential.

At UMES, Das's lab of primarily undergraduates have conducted research in fluid dynamics and nanotechnology that has led to publications, collaborations with MIT and Princeton, and recognition at national conferences. He instills a belief within his students that they are capable of the same great achievements as students at institutions with greater prestige and resources, which they have exemplified by their accomplishments. He has mentored more than 40 UMES undergraduates who have participated in prominent research programs across the country, gone on to graduate school—many on competitive scholarships—at universities like Yale, Duke, and Dartmouth, and are now entrepreneurs, professionals in multinational companies, and researchers at national labs. "There is no absence of talent in minority-serving institutions," according to Das, but that talent must be nurtured in a way that addresses the unique obstacles minority students face--which means building foundations of genuine care for students within our systems.

According to Das, it is important to tell this story because he has interfaced with "the movers and shakers in science" during his fellowship. He describes KITP as a place that "has created this atmosphere of psychological safety," in which scientists "can freely discuss, freely brainstorm, freely debate and challenge each other. This is how science progresses, and KITP has done that extremely well." In the same way he aims to motivate students, he felt encouraged by the other visiting scientists who were receptive to his ideas and made him feel appreciated for his work and contributions.

Participating in the KITP Fellows program served as a "catalyst, energizing all of these reactions" for Das. He emphasizes the value in helping faculty create "pipelines" of opportunity, because cultivating their ambitions enriches entire institutions. After returning to UMES, he shared with students and fellow faculty members the numerous research developments he learned from his peers at KITP. He was also pleased to pass along a message of inspiration: "the rest of the world appreciates what we do." Das came away from his experience as a KITP Fellow with a reinvigorated understanding that the good work he and other minority-serving faculty do for students and for science "is not in vain."

*by Demi Cain*
*KITP Development Coordinator*

# Physicists Work Toward Theory to Describe Pattern Formation in Conserved Fields

When it's time for an E. coli bacterium to divide, proteins inside the single-celled organism start to chase each other around. "There are two types of proteins doing this, collectively," said Fridtjof Brauns, a postdoctoral scholar at KITP. "Thousands of these proteins shuttle back and forth in the cell like this, he said, "and that's a mechanism for the cell to determine its middle."

This cell-division mechanism is but one result of collective protein oscillations, the study of which is the subject of a recent paper published in Physical Review X. Authored by Brauns and Professor Cristina Marchetti of the UCSB Physics Department, it's an investigation of so-called nonreciprocal interactions, which are ubiquitous in active matter and living systems. Collectively these nonreciprocal couplings can result in oscillations and wave patterns, for which the researchers propose a unifying set of equations.

"That's what we try to do in physics; we try to find the common principles that underlie a whole range of phenomena that look quite different at face value," he said. "But if you dig a little deeper, you can actually find common principles."

## FOXES AND RABBITS

Active matter is a term given to systems consisting of collections of "agents" — individual, self-powered units — whose behaviors can give rise to collective effects. Because these agents consume energy, they are said to be out of equilibrium.

"There's this principle of action equals reaction," Brauns said. "That's Newton's Third Law. But if you have a system that consumes energy, then it has internal machinery where this isn't necessarily true anymore; it's nonreciprocal."

A popular analogy for this nonreciprocity, according to researchers, is the predator-prey model.

"A rabbit runs away from the fox, and the fox is chasing the rabbit," Brauns said. Instead of mutual attraction or mutual repulsion as would be demanded by Newton's Third Law, one is attracted to the other while the other flees.

In the researchers' oscillating protein model, this non-reciprocal interaction is combined with an attractive force that only acts between agents of one species and leads to their segregation in space, like deer that like to stay close together in a herd. Mathematically, this segregation is described by the same equations that describe the phase separation of oil and water.

But this is active matter, so the action doesn't stop there, Marchetti said. "Instead of making just this static bulk phase-separation, the entire system starts moving. Not only do the proteins start moving or oscillating, they also form a pattern." These emergent patterns can look like stripes, or waves, as the proteins at the interface collectively chase and flee each other, she added.

*Oil molecules will stick to each other, but collectively segregate themselves from the water molecules*

To describe these spontaneous, pattern-forming behaviors, the researchers combine an equation called the Cahn-Hilliard equation, which describes the phase separation, and the FitzHugh-Nagumo model, which describes the emergence of oscillations and waves through nonreciprocal interactions.

An important aspect of the research model is that it describes conserved fields.

"It just means that the numbers of the constituents that undergo these dynamics stay the same," Brauns explained, as opposed to systems in which members degrade or are created — the populations of foxes and rabbits are stable and fixed. "That number conservation gives the theory its mathematical features and allows us to gain physical insight that wasn't possible before." Up until this point, the models for pattern formation have often not considered conserved fields, though conserved systems are common in biology and also in synthetic material systems such as chemically driven colloidal particles.

LARS BILDSTEN

*A murmuration, or flock of starlings, at UCSB's Sedgwick Reserve*

Research on pattern formation in biology has roots that go back more than 70 years, to the work of Alan Turing, the famed mathematician and computer scientist.

"He wrote a very prescient and seminal paper in 1952 on how he imagined the chemical molecules or a cell in a developing organism can generate patterns like the stripes of a zebra," Brauns said. "And that has been the guiding idea since then." Turing's biophysical pattern work wasn't taken that seriously for decades, Brauns added, but the explosion of interest in pattern formation in the 1990s and also subsequent technological advances allowing people to see active components in action fired up research into the topic.

Aside from insights into developmental biology, understandings of pattern formation may also apply to the field of natural computing, in which the data processing units work by oscillation.

"There are some people who think about what the cells are doing internally as a sort of computation," Brauns said. One classic example is the human brain, whose neurons exhibit the same behavior of electrical spiking and collective traveling waves as they transmit information. Whether they are natural, like animal cells in the middle of development, or manmade, like circuits, from a mathematics perspective, "many of the phenomena look the same or very similar, giving us hope that we can develop a unified understanding," he said.

*by Sonia Fernandez*
*UCSB Public Affairs, Senior Science Writer*

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